



ontario hydro research division

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To: Dr. D. Mills
Director of Research

HOLOGRAPHY GOES ON TOUR AT OHRD

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A travelling holography cart made its way to a number of testing labs at the Ontario Hydro Research Division to demonstrate the feasibility of performing holographic nondestructive testing in an unisolated environment outside of the holography laboratory. We were able to obtain strain or vibration patterns on concrete, rock, rubber, and steel specimens.

Fig 1. Dave Mader (Hydro) and Hua Lu (Ryerson) pose with their holography cart.



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INTRODUCTION

Holography has been successfully demonstrated outside of our holography lab in a simulation of the holographic nondestructive testing technique in the field environment. In the past, we have been tied to a large vibration isolation table located in our holography laboratory. Now, for the first time, we have placed holographic apparatus on the cart seen in Fig 1 to make the technique transportable. To obviate the need for vibration isolation in this demonstration, we used a pulsed laser rather than a continuous laser. The pulsed laser was a Continuum model YAG 661-10 laser that pulses 10 times per second. After a hologram is made to store the initial shape of the object under test, each successive pulse produces a new interferometric fringe pattern in immediate response to the shape (and position) of the object as it is loaded. The wealth of data so obtained was stored on video tape.

A brief description of the holographic technique is given in a previous report/1/. A schematic diagram of the apparatus is given in /2/ as a proposed apparatus. The size of the object studied in /1/ was about 1 m by 1 m. In contrast, most of the specimens studied in this report were much smaller.

THE SEVEN TRIALS

Trials were done in conjunction with the following research departments:

- Chemical (rubber seal for expansion joints in the Pickering NGS pressure relief duct)
- Civil (three concrete specimens and one rock specimen)
- Mechanical (steel pressure vessel, heat exchanger shell)

Trial 1. Rubber seal. The test rig for the seal material used in the Pickering NGS pressure relief duct is shown in Fig 2. Steel strips marked H and HH are bolted to a pressure vessel to affix the seal. A splice in the material is to be seen in the middle of the figure. The seal surface is concave because a vacuum pump has been used to reduce the pressure 30 kPa below atmospheric pressure.

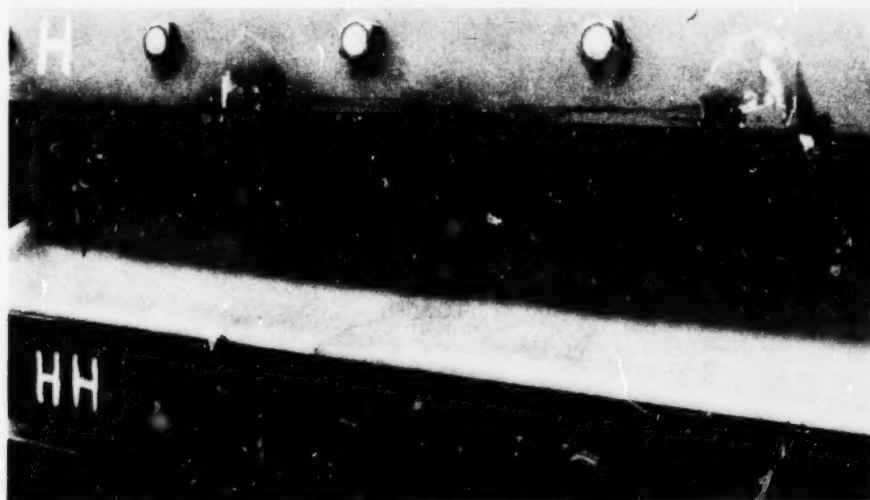


Fig 2. Ordinary photograph of rubber seal test rig.

A differential load on the seal was applied by a load applicator that was removed before this picture was taken. This load applicator was basically a sheet of Plexiglas sealed to the rig and the rubber seal, with a passageway to apply pressure. The position of the load applicator is indicated by some sealant seen on strips H and HH that remained there when the applicator was removed.

Real-time holographic interferometry was used to obtain the fringe pattern of the splice region, shown in Fig 3, caused by a slight pressure change in the load applicator. In this figure, the fringes are seen to change direction as they cross the boundaries of the splice. Thus holography is able to find areas of anomalous strength in the seal material.



Fig 3. Fringe pattern of splice region in pressure relief duct seal material.

Trial 2. Concrete compression test. A cylindrical concrete specimen, 15 cm in diameter and 30 cm long, was compressed in a testing machine. The bulls-eye on the right side of the fringe pattern seen in Fig 4 is an anomalous area.



Fig 4. Concrete cylinder in compression.

Trial 3. Bending of concrete beam. A four point loading test of a concrete beam specimen gave fringe patterns such as the typical pattern shown in Fig 5. This pattern was caused by a slight increase of load in the middle range of the loading regime. Here the fringes are approximately equally spaced parallel straight lines, which is a fringe pattern that indicates the occurrence of translation or tilting.

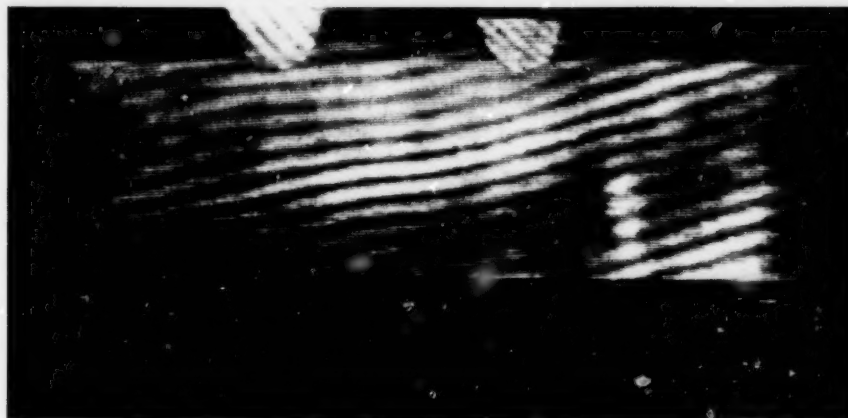


Fig 5. Four-point loading of concrete beam

Trial 4. Concrete core sample. A concrete core sample, obtained with a coring drill, was compressed in an extra-rigid testing machine to reduce motion caused by deformation of the frame of the testing machine. As seen in Fig 6(a), a view of the sample in a no-load condition, many of the exposed stones are large and dark coloured. In (b) we have an intermediate loading condition. The distribution of strain from stones to cement paste is indicated by the spacing between fringes, and by their curvature. The view in (c) was taken shortly before failure with a relatively large differential load. Over most of the sample the fringe density is too great to be resolved. However, the large stone near the top left corner was rigid enough to resist excessive deformation and to show a few fringes. The curvature of these fringes indicates bending of the stone.

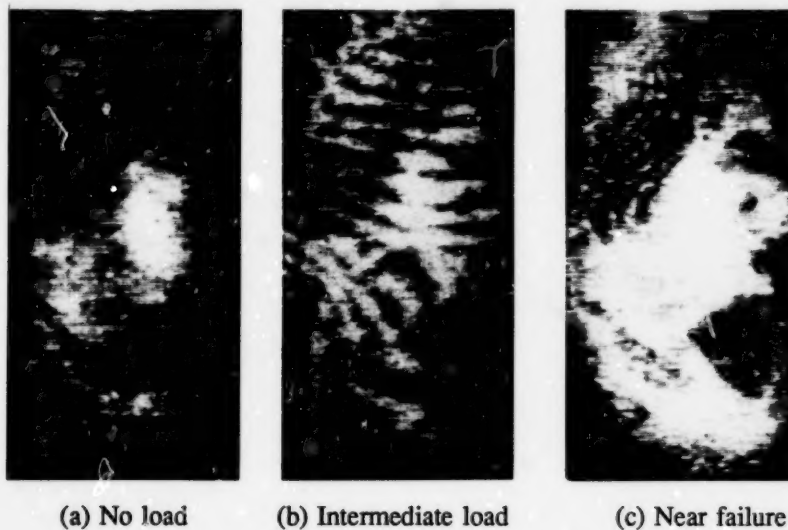


Fig 6. Concrete core sample

Trial 5. Rock specimen. A 6.3-cm-diameter core sample drilled from rock was tested in compression. This sample, as expected, showed much greater homogeneity and stiffness than concrete samples. Only a few holograms had to be made to cover the entire loading regime. Fig 7 illustrates the biconical stress distribution expected theoretically for compression between non-slipping plates. (The dark marks in the figure are ink marks.)



Fig 7. Cylindrical rock specimen in compression.

Trial 6. Vibration of heat exchanger shell. One section of the shell of a heat exchanger in a test loop was observed to find out if holography could detect vibration modes. With water flow through the shell side of the heat exchanger a wide variety of fringe patterns was seen. These patterns are a combination of vibration deformation and local rigid-body motion of the shell; an example is shown in Fig 8. Of special interest is the hinge effect seen at the bolted joint between shell sections on the left side of the photograph. The flanges on each side of this joint each show a rigid-body-motion fringe pattern of parallel, straight, equally-spaced fringes. However, the directions of the two fringe patterns are different. This difference indicates a different tilt angle of the two flanges.



Fig 8. Vibration of heat-exchanger shell. Rigid-body motion is combined with vibration.

In Fig 9 we show a pattern, selected from the video tape, where there was little rigid-body motion. What remains is local deformation due to vibration. There are three bulls-eyes in evidence in the top half of the photograph; from this small number, we conclude that this is a low order vibration mode. This mode was induced by the test conditions, which included water flow on the shell side, and vibration of a number of U-tubes.



Fig 9. Vibration of heat-exchanger shell. Vibration mode alone.

Trial 7. Steel Pressure Vessel. A small pressure vessel fabricated from a 30-cm length of 10-cm diameter pipe was studied. The wall of this vessel had an internal, circumferential crack that had been deliberately introduced. The fringe pattern that was obtained with a pressure change of 2 MPa is given in Fig 9. Two wires leading to a strain gage are seen in the left half of the picture; the fringes on these wires indicate their motion. The crack, which had been previously fatigue cycled to a leak condition, causes a large disturbance in the ordinary expansion fringe-pattern of a pipe under pressure.



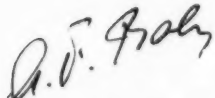
Fig 9. Cracked steel pipe under pressure.

CONCLUSIONS

A pulsed laser gives holography the freedom to operate in a field environment. Our tour of various sites at the Research Division laboratories demonstrated our ability to obtain fringe patterns on various specimens: concrete, rock, steel, and rubber. Each trial took one day, on average. This successful tour lends confidence to pursue further work toward application of holography in the field to detect flaws, defects, or non-incipient faults in power system equipment.

Excellent cooperation was given by our clients, who suggested experiments, offered the use of their laboratories, operated testing machines, and joined with us in witnessing the trials. We thank Rick Lewak, Cal Breckenridge, Gil Caratin, Ed McColm, Doug Wilkinson, Joe Aloisio, Carl Hernes, Duncan McKay, Holly Anderson, Rick Black, Martin DeMontmorency, Mike Flaman, and John Herring.

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